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A New Search for the Neutron Electric Dipole Moment

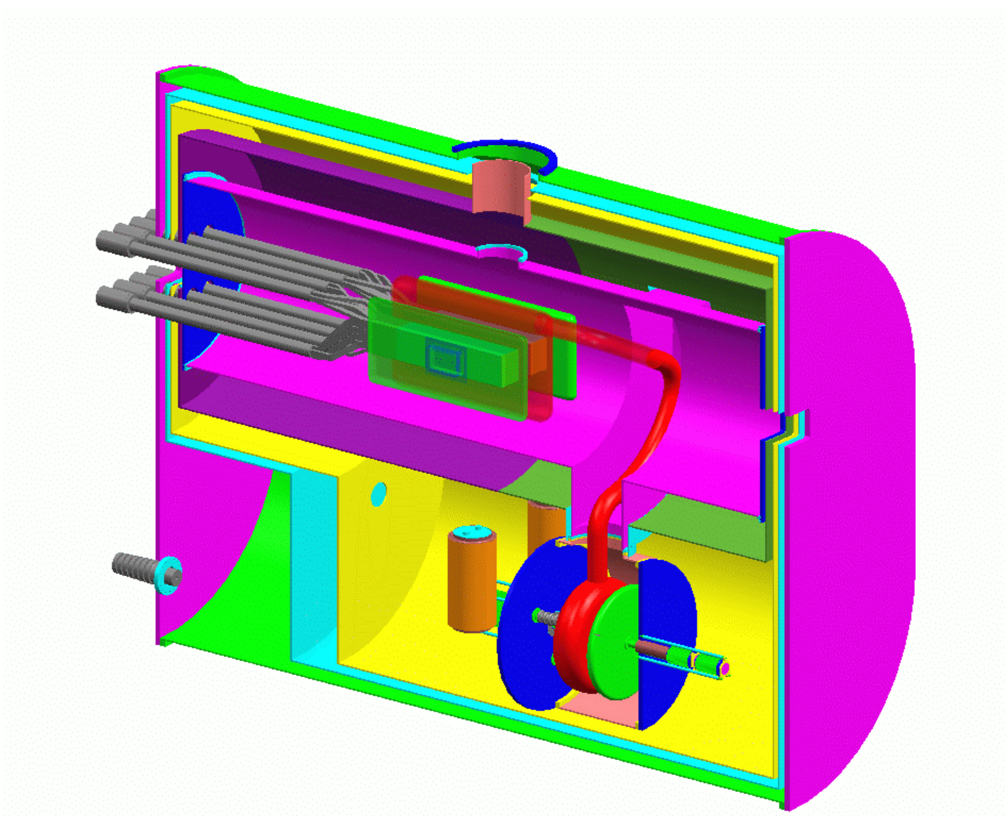
Funding Pre-proposal

submitted to

The Department of Energy

prepared
by

The EDM Collaboration



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Summary

The possible existence of a nonzero electric dipole moment of the neutron is of great fundamental interest in itself and directly impacts our understanding of the nature of electro-weak and strong interactions. The experimental search for this moment has the potential to reveal new sources of T and CP violation and to challenge calculations that propose extensions to the Standard Model. In addition, the small value for the neutron EDM continues to raise the issue of why the strength of the CP violating terms in the strong Lagrangian are so small. This result seems to suggest the existence of a new fundamental symmetry that blocks the strong CP violating processes.

The goal of the current experiment is to significantly improve the measurement sensitivity to the neutron EDM over what is reported in the literature. The experiment has the potential:

a) to measure the magnitude of the neutron EDM; or
b) to lower the current experimental limit by one to two orders of magnitude.

Achieving these objectives will have major impact on our understanding of the physics of both weak and strong interactions.

The experiment is based on the magnetic resonance technique of rotating a magnetic dipole moment in a magnetic field. We describe in this report a new method to make a precision measurement of the neutron precession frequency under the influence of an electric field. The strategy is innovative and unique. It features:

a) using a dilute mixture of polarized ^{3}He in superfluid ^{4}He as a working medium for the very high electric field environment;
b) determining in situ the magnetic field experienced by the neutrons, using a direct SQUID measurement of the precession frequency of the ^{3}He magnetic dipoles; and, finally,
c) making a comparison measurement of changes in the precession frequency, under E field reversal, of the neutron and ^{3}He components of the fluid, where the neutral ^{3}He atom does not have an EDM.

Additional innovative features include loading the neutron trap with UCNs through a superfluid ^{4}He phonon recoil process, introducing highly polarized ^{3}He atoms into the trap in order to align the trapped UCN spins, operating the trap at extremely cold temperatures (~300 mK) to minimize UCN losses at the walls, and, finally, detecting the n-^{3}He precession frequency difference, independently of the SQUID detectors, by viewing the induced ^{4}He scintillation light with photomultipliers. The process of validating these techniques and determining their limits is well started, but realization of the experiment requires the resources requested here in order to fully exploit this new approach. A two-year study of this measurement strategy has not revealed any fatal problems.

This search for the neutron electric dipole moment is a major technical challenge and requires a research team with a broad base of technical knowledge and extensive research experience. We have assembled a growing group of research physicists (currently over 30 physicists from fourteen institutions), who are committed to taking on this challenge. Indeed, some are world experts in their specialties. A number have experience with previous EDM experiments. In addition, we anticipate that the fundamental and innovative character of this physics research will attract outstanding postdoctoral physicists and graduate students from the research institutions in the collaboration, and will generate a set of significant thesis projects.

This project is challenging at both small and large scales. It requires, for example, development of special low noise SQUIDs, laser techniques to measure high electric fields, and hardware to generate highly polarized ^{3}He beams. It also requires operation with very high electric fields and construction of large scale vacuum and cryogenic systems capable of handling over 1500 L of superfluid ^{4}He. In the UCN traps, we require a ^{4}He purity with respect to ^{3}He, that can be controlled at the level of one part in 10^{14}.

The equipment to achieve all of this will require three years to manufacture, assemble and commission as well as $11M of construction funds that include 40% contingency, institutional burden, and escalation. We regard this effort as a ten year project for which we are now in about the third year. The seed money (~$5M of salaries and equipment) for preliminary design and initial validation tests of the experiment, has come from discretionary funds at LANL. The development work, described throughout the pre-proposal, has removed the most serious concerns of feasibility, and at its conclusion at the end of FY’04, should remove the technical risks summarized in Appendix A. We are now seeking DOE funds for construction of the full project in FY05-07. Though we will seek support from other agencies at a future time as an offset of the burden on DOE, until these funds are secure, we ask DOE for the full amount.

The physics goals of this experiment are timely and of unquestioned importance to modern theories of electro-weak and strong interactions. The technique builds on 30 years of experience with neutron EDM experiments and seeks to improve the current EDM limit by a factor of 50 to100. The collaboration includes researchers with expertise developed in previous neutron EDM searches and in the new technologies required for this innovative technique. We request funds to construct this important and ambitious project during the period FY05-FY07.